Economic Metrics for Combining Risks

US EPA Region/ORD Science Topic Workshop on Cumulative Risk Assessment

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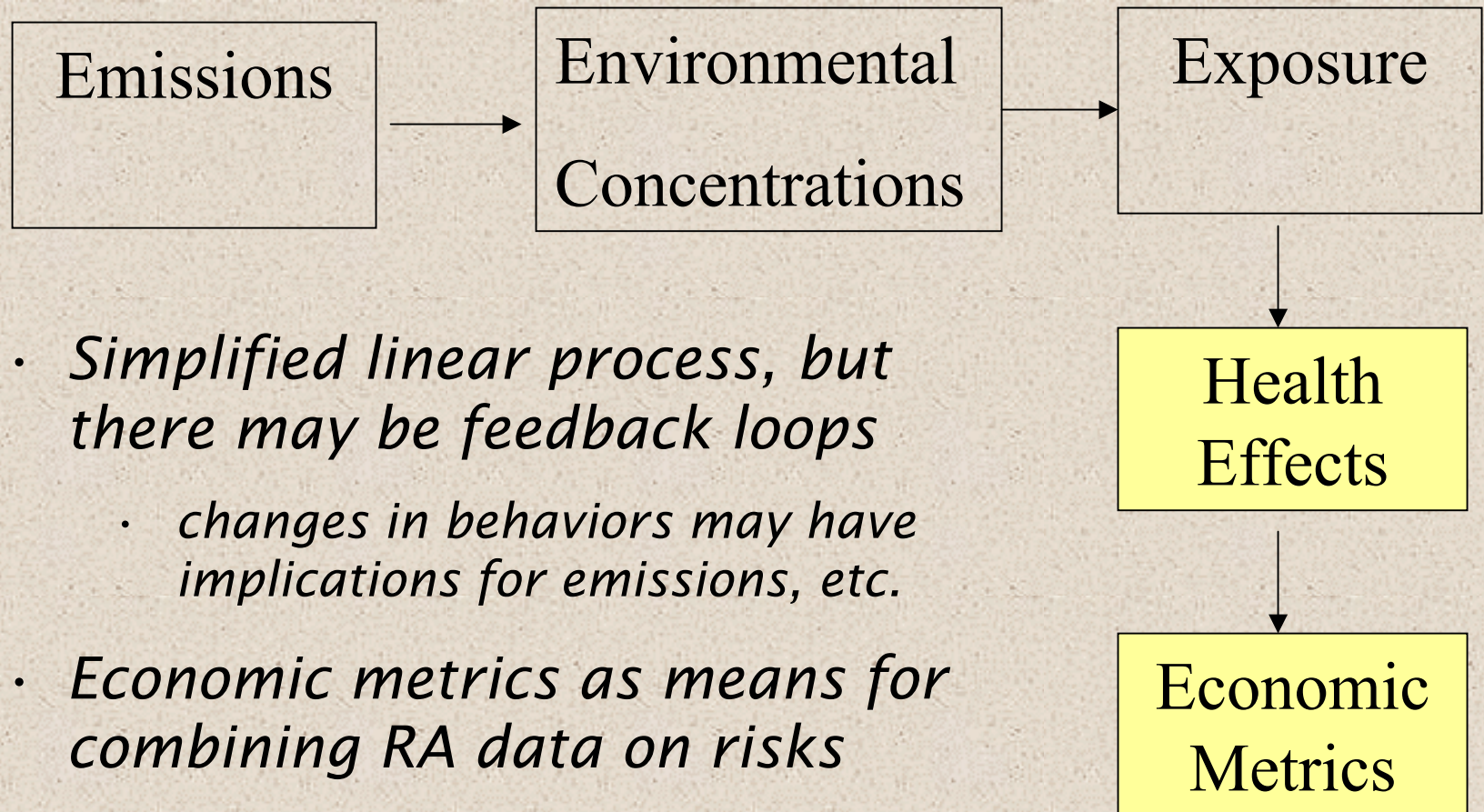ENVIRONMENTAL ECONOMICS

Outline

- *Summary of data needs for economic metrics*
- *Types of economic metrics*
  - *Costs of Illness, DALYs, QALYs, WTP*
- *Notes on the impact of cumulative risk for economic metrics*

Steps to Economic Metrics

Emissions → Environmental Concentrations → Exposure → Health Effects → Economic Metrics

- *Simplified linear process, but there may be feedback loops*
  - *changes in behaviors may have implications for emissions, etc.*
- *Economic metrics as means for combining RA data on risks*

Foundations for Economic Metrics

- *Economic metrics are founded on how individuals' value desirable things.*

- *These values are built upon three **key principles:***
  - ***Consumer Sovereignty**: individuals generally know what is in their interest and act accordingly*
  - ***Constrained Tradeoffs**: individuals make tradeoffs between desirable things because available resources are limited (e.g, income)*
  - ***Rationality:** given their preferences the tradeoffs individuals make are systematic*

Defining "Health Effect"

- **Three possibilities** for defining H
  - **H affects well-being** and functioning
    - mortality, injury, asthma attacks, cancer, etc.
  - **H is an indicator** of other effects that affect well-being, but has no direct effect
    - increased hormone level
  - **H has no direct or indirect affect** on well-being
    - change in organ weight (absent other symptoms)

- Economic metrics fully accommodate only the **first category**

Defining Risk

Economic metrics require a set of probabilities to represent the *expected changes in risk* to an individual

- thresholds alone can't be used
- risk characterization must represent expected changes in population outcomes
  - bounding or conservative risk estimates will lead to a biased estimate of benefits

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Timing of Risk Reductions

Economic metrics require information on the timing of risk reductions when there are lags between exposure reduction and risk reduction.

- timing affects the present value of costs
- timing affects expected length of time with effect
- people exhibit positive time preferences, preferring risk reduction now to risk reduction later

Types of Economic Metrics

- *Cost of illness ($)*
  - health care costs, lost production
- *Health state indices* (weighted years)
  - Disability Adjusted Life Years (DALY)
  - Quality Adjusted Life Years (QALY)
- *Willingness to Pay* for risk reduction ($)
  - willingness to accept included

My focus will be on QALY and WTP metrics
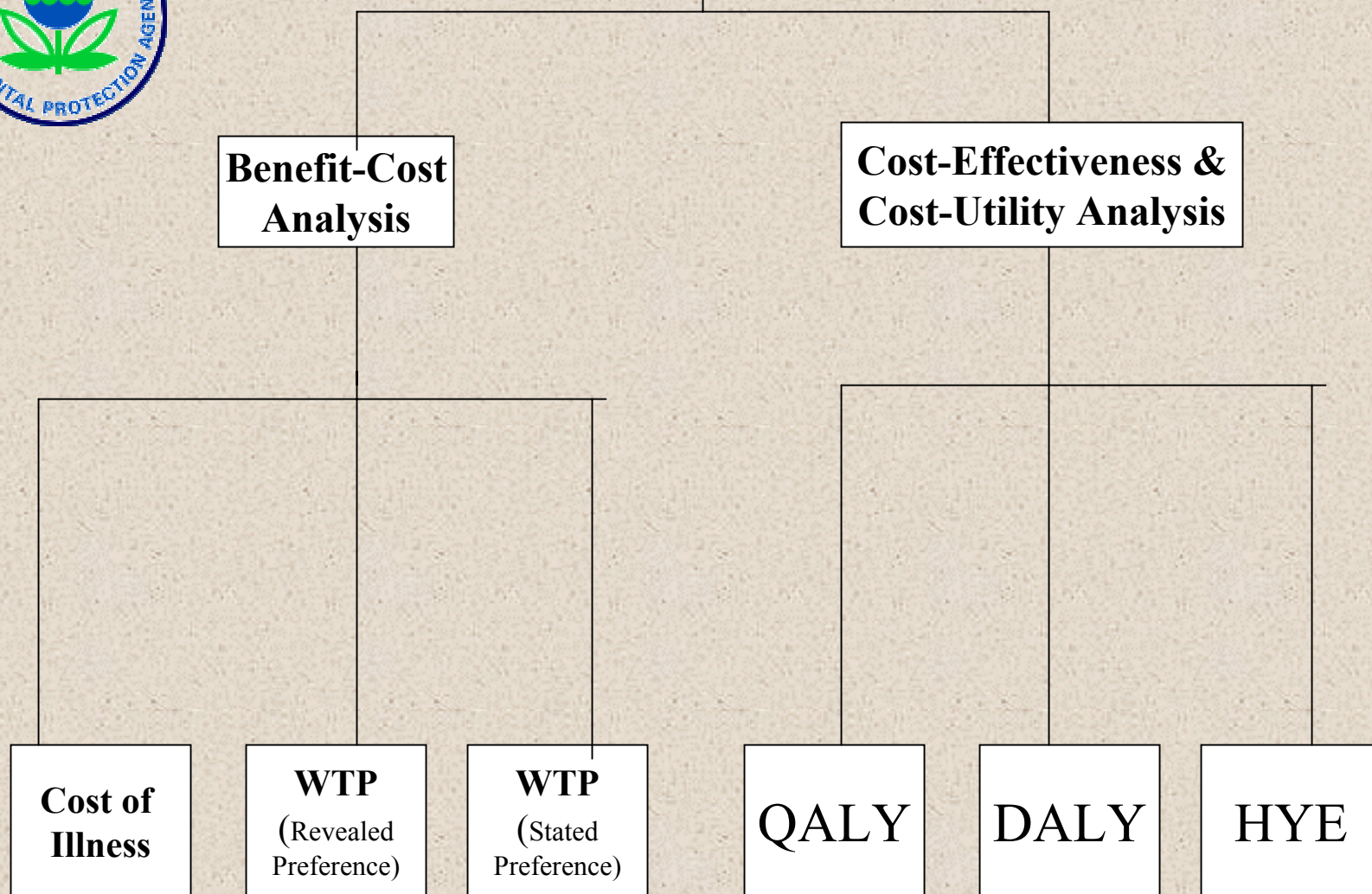
Cost of Illness

- *Each health effect converted to $-equivalent based on lost production and health care costs*

- *Clearly defined and measurable*

- *Limited measure*
  - *not necessarily based on individual preferences*
  - *incomplete, does not include pain and suffering*
  - *price of health care may not equal costs*

Health State Utilities

- QALYs and DALYs noted in "Framework for Cumulative Risk Assessment"
  - there are others (e.g., Healthy Year Equivalents)
- health conceptualized as having 2 dimensions
  - longevity (years)
  - health-related quality of life
- outcome is total years weighted by quality in each year

Disability Adjusted Life Years

- *measures "burden" of condition compared with an optimum health and longevity profile*
  - *Life span based on "standardized" survival curves*
    - *Japanese Life expectancy assumed for global application*
      - *Females = 82.5 years*
      - *Males = 80.0 years*
  - *quality measure of a given health state is based on "person trade off" method*
  - *U.S. - specific DALYs are being developed*

Disability-Adjusted Life Years (DALYs)

- *Age-weighted* to give most weight to most productive ages
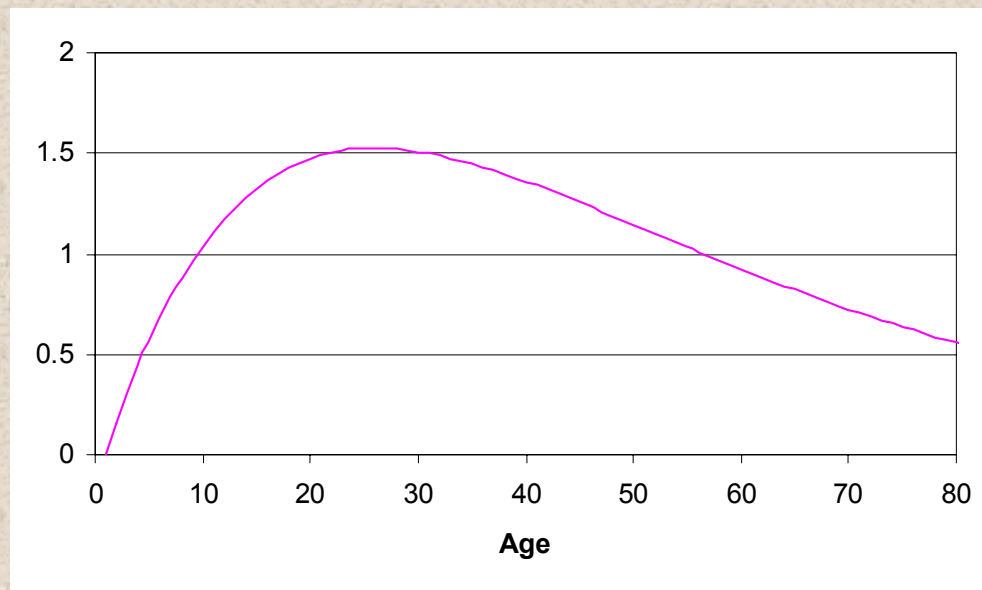
Quality-Adjusted Life Years

- *Well-being is defined by health profile over time*
  - *Utility = U(Quality, longevity)*
    - *note that income does not enter directly into this framework*
- *Most widely used in cost-effectiveness analysis*
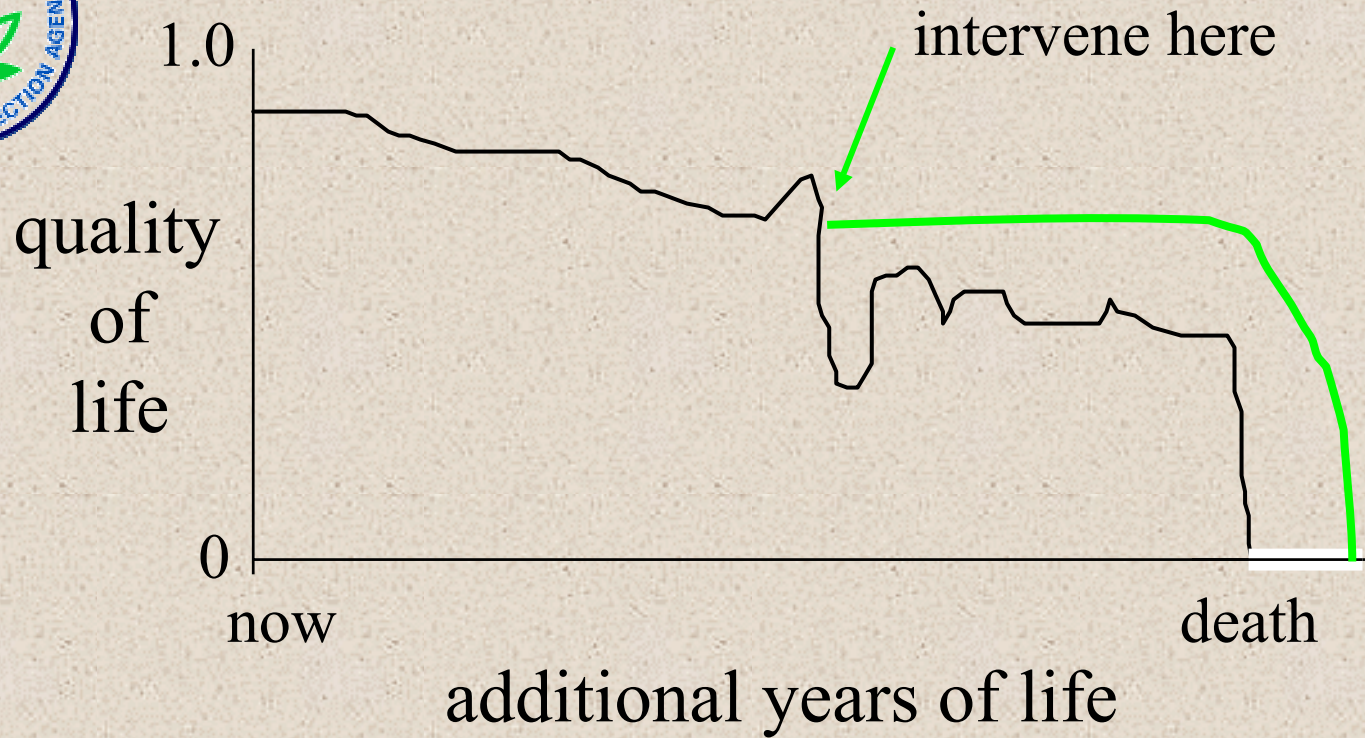 - *choose intervention with lowest $ per QALY*

Quality Adjusted Life Years

- Total QALYs is given by multiplying duration in health state & quality in that state, then aggregated
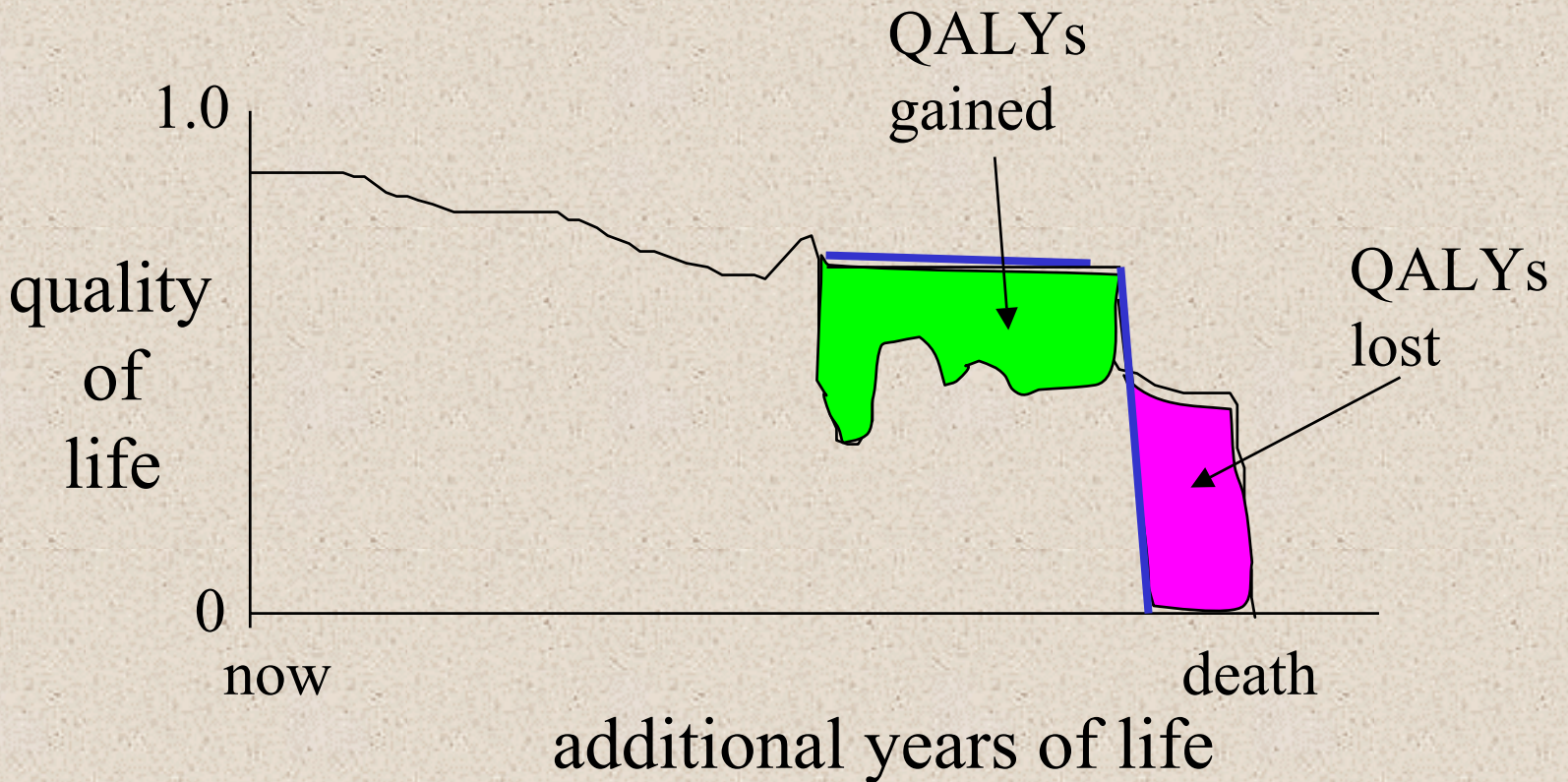
$$QALYs = \sum_{i=1}^{N} q_i T_i$$

  - q = "Health-related quality of life" (HRQL)
    - q=0 for death and q=1 for perfect health
    - q can be less than zero for states judged to be worse than death.
  - T = duration (years)

The ideal outcome is an intervention that improves quality and extends life
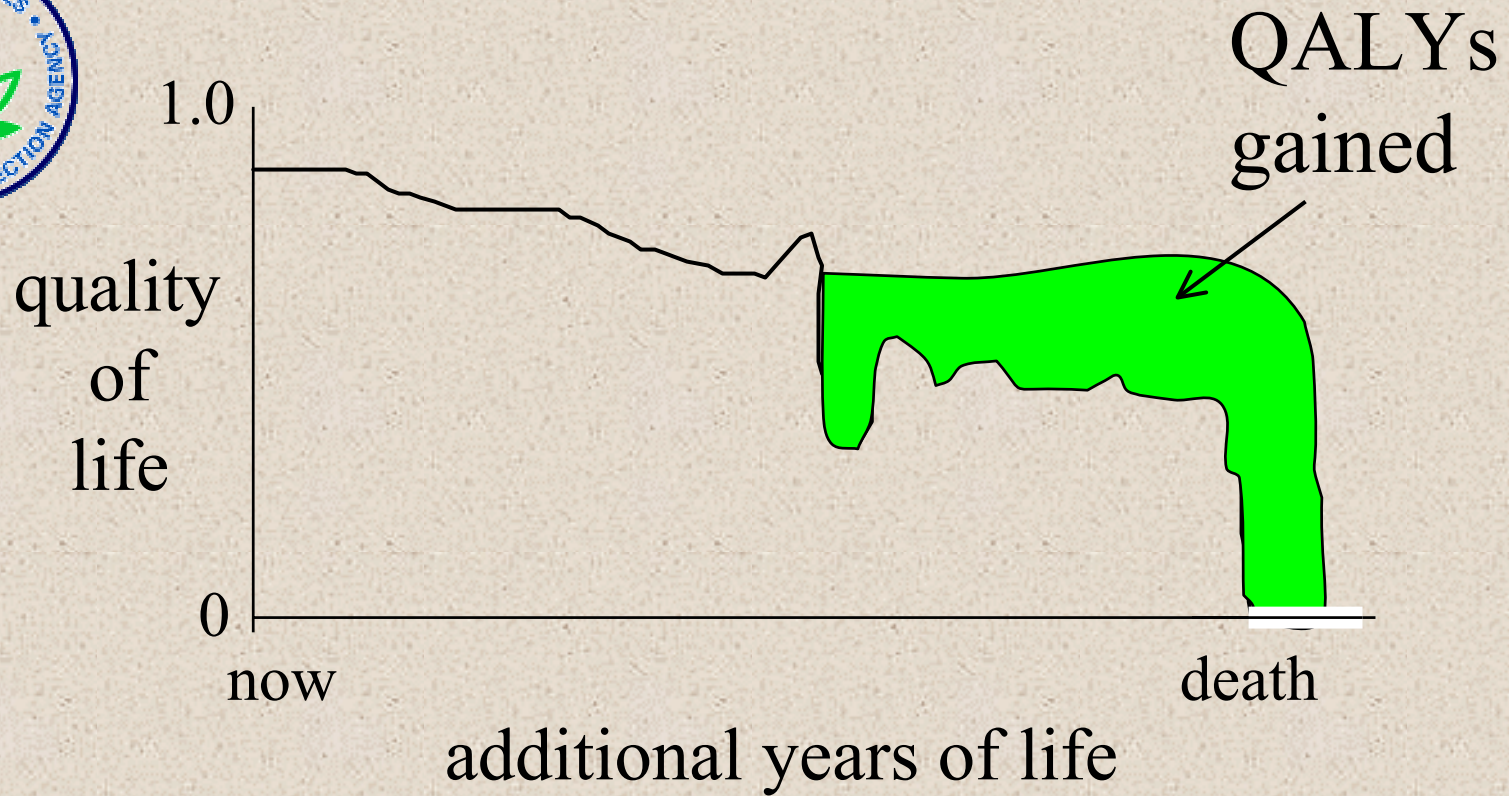
The ideal outcome is an intervention that improves quality and extends life

A less ideal outcome is an improvement in quality but a reduction in lifespan
*   - QALYs lost are balanced against QALYs gained*

Figure from a presentation by Jim Hammitt

Another less ideal outcome is a reduction in quality but an extension of lifespan
    - Again, QALYs lost are balanced against QALYs gained

Some QALY Assumptions

There is a constant proportional tradeoff between quality and time: q does not depend on T

For example...

If one is indifferent between

(nerve disease for 40 yrs) and (perfect health for 30 yrs)

Then one is indifferent between

(nerve disease for <u>20</u> yrs) and (perfect health for <u>15</u> yrs)

This doesn't generally hold empirically

Some QALY Assumptions

People are risk neutral with respect to lifespan: *lotteries on longevity evaluated solely by life expectancy*

· *This implies that, for example, one is indifferent between*

  A) 30 yrs in good health, and

  B) a 50/50 lottery between 15 yrs in good health and 45 yrs in good health

  Empirically, risk attitudes differ across individuals, but risk neutrality may represent the average case.

Measuring "Q"

- Surveys can elicit "community preferences"
  - visual analog scale
  - time tradeoff questions
    - yrs in health state x compared to yrs in perfect health state
  - standard gamble questions
    - given a health state, what risk of death would you accept to return to perfect health?
  - person tradeoff
    - extending life of healthy people relative to non-healthy
    - extending life of healthy people relative to improving quality for non-healthy

Measuring "Q"

- Estimated "Q" depends on how the question is asked
  - *Stylized findings are that Standard Gamble produces highest Q's, followed by Time Tradeoff, then Visual Analog Scales*

- *Huge literature* with quantitative estimates
  - Harvard Center for Risk Analysis

    http://www.hsph.harvard.edu/cearegistry/
    - *in particular "catalog of preference scores"*

Additional Considerations (QALYs)

- *Equity considerations*
  - *interventions for young preferred to old*
  - *life extensions for healthy preferred to life extensions to less-healthy*
- *Economic criticisms*
  - *assumptions are restrictive and don't reflect actual preferences*
  - *concern about quality of surveys (data)*

Willingness to Pay

- *Well-being is defined in a general utility function:* Utility=(health, all other goods)

- *Most widely used in benefit-cost analysis*
  - *"efficient" policy is where benefits minus costs are greatest*

- *Accommodates changes in different health and risk outcomes by expressing them in dollar terms*

Willingness to Pay

- *Willingness to pay (and willingness to accept) is the tradeoff between between wealth and health*

$$U(Healthy; wealth\text{-}WTP) = U(Ill; wealth)$$

or

$$U(Healthy; wealth) = U(Ill; wealth+WTA)$$

- *WTP and WTA should generally be close to one another for minor illness (but maybe not for serious illness)*

Willingness to Pay

Willingness to pay *is...*
- *One's own WTP for one's own risk reduction*
  - *WTP for others may be included under strict conditions*
- *Affected and constrained by income*
  - *willingness to pay includes "ability to pay"*

Willingness to pay *is not...*
- *A measure of on ex post compensation experiencing health effect*
  - *WTP is measured ex ante for risk reductions*

WTP Assumptions

- Individuals are willing to *tradeoff health risks and wealth*

- Individuals *perceive risks accurately* (or at least systematically) and behave in their own best interest

- Few assumptions on how individuals tradeoff quality and longevity
  - there is no fixed definition of "quality"
  - empirically determined

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Measuring WTP

- *Economists seek examples where people appear to tradeoffs between risk and dollars:*
  - *Workplace: how much additional wages to workers require to take risky jobs?*
  - *Consumer Markets: how much do individuals pay for safety devices and safer vehicles, etc.?*
  - *Surveys: how much do individuals state they will pay for a specified risk reduction*
- *There is a large body - and a wide range - of empirical estimates using these data*

Measuring WTP

- *Estimates distinguished by mortality and morbidity*
  - *mortality: value of statistical life*
    - · *normalization of this WTP for risk change*
      - *VSL = (WTP for risk change) / (risk change)*
      - *if risk change is 1/10,000 and WTP is $500 then VSL = $500 / (1/10000) = $5 million*
  - *morbidity (illness): value of statistical illness (similar to above)*
    - *each illness is unique to some extent (severity, frequency, duration)*
    - *requires unique research or extrapolation from others*

Measuring WTP

- *Method matters*
  - *surveys, wage-risk, averting behaviors rarely converge*

- *Limited literature on non-fatal health effects*
  - *studies are individually expensive*
  - *relatively small research community*

Aggregate Measure

- Aggregate measure (metric) is *total WTP* for set of health risk reductions
  - VSL for mortality risks
  - morbidity estimates for non-fatal illness
- typically assume these are *additive*
  - effect of other risks on WTP is often ambiguous
  - WTP for reduced risk of sets of risk reductions may be more or less than sum of WTP for individual risk reductions

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Additional Considerations (WTP)

- *Equity Considerations*
  - *WTP is related to income*
  - *empirical results suggest that young and old value mortality reductions similarly*
    - *theoretical results suggest otherwise*
  - *recent results suggest health status has little effect on valuing mortality risks*

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Notes on Cumulative Risk and Economic Metrics

- Assumes causality and dose-response issues are resolved (e.g., chemical mixtures)

- "Specific-population" focus of CRA implies need for population specific measures, particularly WTP
  - WTP is a function of income and opportunities to avoid risk or mitigate health impact

Notes on Cumulative Risk and Economic Metrics

- *WTP applies only to risk changes. It does not characterize a given risk level.*
  - *DALYs characterize stock*
- *Cumulative risk can provide background level of health risks to population*
  - *Generally, WTP for a given risk reduction increases with level of background risk*
    - *we lack great deal of data on the magnitude*
  - *QALY weights independent of background risks*

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More Information

- Guidelines for Preparing Economic Analysis *(2000)*
  - *Covers willingness to pay and benefit-cost-analysis*
- Non-Cancer Valuation Handbook
  - *Focusing on willingness to pay and cost of illness for non-cancer health effects*
- Primer on the use of QALYs for Environmental Policy (in progress with OGWDW)
  - *provides background information on quality-adjusted life years, and literature survey*
- Health Valuation Conference (Feb 03)